WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review on Experimental Research on the Utilization of Pet Fiber As A Construction Material in Concrete

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ABSTRACT :

The increasing environmental concerns and the accumulation of plastic waste have led to the exploration of sustainable solutions in construction materials. One such approach is the incorporation of Polyethylene Terephthalate (PET) fibers in concrete to enhance its mechanical properties while addressing plastic waste management. This review paper presents an overview of various experimental studies on the utilization of PET fibers in concrete. The key aspects examined include the effects of PET fibers on compressive strength, tensile strength, flexural strength, and durability. Additionally, the influence of PET fiber content, size, and shape on concrete performance is discussed. The review highlights that PET fibers can significantly improve the tensile and flexural strength of concrete while reducing shrinkage and crack propagation. However, optimal fiber dosage and proper mixing techniques are crucial to achieving uniform dispersion and enhanced performance. The study concludes that PET fiber-reinforced concrete is a promising sustainable material, with potential applications in non-structural and lightweight construction.

Key Words:- Environmental concerns, Construction materials, PET fibers on compressive strength, Tensile and flexural strength

Introduction :

Concrete is one of the most widely used construction materials due to its high compressive strength, durability, and ease of production. However, conventional concrete has certain limitations, including brittleness, low tensile strength, and susceptibility to cracking. To enhance the mechanical properties and sustainability of concrete, researchers have explored the incorporation of fiber reinforcements, including synthetic and natural fibers. Among these, Polyethylene Terephthalate (PET) fibers, derived from recycled plastic waste, have gained significant attention due to their environmental benefits and promising effects on concrete performance. The disposal of PET waste, primarily sourced from used plastic bottles, poses a major environmental challenge. The non-biodegradability of PET materials leads to severe ecological impacts, including landfill accumulation and ocean pollution. The integration of PET fibers in concrete presents a sustainable solution by repurposing waste materials while improving the structural properties of concrete. Various experimental studies have investigated the influence of PET fiber on the workability, strength, durability, and crack resistance of concrete. This review paper aims to summarize and analyze existing experimental research on the utilization of PET fibers in concrete. It examines the effects of PET fiber on fresh and hardened concrete properties, optimal fiber dosage, and potential challenges associated with its application. Additionally, the study explores the environmental and economic advantages of PET fiber-reinforced concrete, highlighting its viability as a sustainable construction material.

Literature Review :

Karthikeyan S et al (2024) was study the dual benefit of improving construction materials and promoting environmental sustainability. It would be interesting to further explore the long-term durability, chemical resistance, and fire behavior of PET fiber-reinforced concrete. Enhanced ductility and impact resistance make PET fiber concrete a viable option for structures subject to dynamic or impact loads. The use of PET fibers not only boosts the structural performance of concrete but also provides a sustainable solution to plastic waste management. PET fibers (50 mm in length and 3 mm in width) were added to M30 grade concrete in varying proportions *0%, 0.25%, and 0.5% by volume*. Address environmental concerns by repurposing plastic waste into useful engineering applications. To explore the use of PET fibers as a construction material in concrete to improve its mechanical properties. Research on incorporating PET fibers into M30 grade concrete highlights innovative ways to enhance concrete's performance while addressing environmental concerns. Concrete, being the construction material that is extensively employed, possesses various limitations despite its adaptability in building projects. It exhibits weakness when subjected to tension, has restricted ductility, and offers minimal resistance against cracking. Concrete is widely used in construction due to its high strength. The aim of this study is to conduct experimental research on the utilization of PET fiber as a construction material in concrete, which is technically sound and environmentally safe. The use of PET fiber in various engineering applications can solve the problem of disposal of plastic waste. PET fiber can be used in concrete to improve its ductile parameters. PET wires of 50 mm in length and 3 mm in width are used in this work. The tests conducted on M30 grade concrete included assessments of its strength in compression, strength in split tensile, strength in flexure, and resistance to impact. The percentages of addition were 0 %, 0.25 % and 0.5 % volume of fiber. The impact properties of PET fiber concrete were studied. Test results showed that there is improvement in compressive strength, split tensile strength, flexural strength and a significant increase in impact resistance of concrete after the addition of PET fibers.

Jong-Pil Won et al (2024) this study investigated the long-term durability performance of recycled polyethylene terephthalate (PET) fiber-reinforced cement composites. Specifically, chloride permeability, repeated freeze–thaw, and various chemical environment tests were conducted. Five types of chemical environments were considered, alkaline, salt, CaCl2, sulfuric acid, and sodium sulfate. Recycled PET fiber-reinforced cement composite was not different from plain concrete in terms of chloride permeability. The repeated freeze–thaw test results showed excellent endurance characteristics of recycled PET fiber-reinforced cement composite. Recycled PET fiber-reinforced cement composites showed reduced compressive strength in alkaline and sulfuric acid environments. However, recycled PET fibers and recycled PET fiber-reinforced cement composites were largely unaffected by salt, CaCl2, and sodium sulfate environments.

S.M.D.V. Suraweera et al (2023) the use of recycled polyethylene terephthalate (pet) fibers in concrete has gained attention as a potential reinforcement material due to its availability and sustainability. PET is a polymer widely used in food packaging and textiles, and its recycling into fibers for concrete is an environmentally friendly solution. Here’s a summary of the key aspects investigated in the study on PET fiber-reinforced concrete (PET-FRC). The addition of PET fibers can impact the workability of concrete. The dimensions, volume, and amount of PET fibers can reduce the flow ability and ease of mixing, making it harder to work with unless properly managed. The ratio between water and cement is crucial for workability and hydration. Studies suggest that pet fibers may affect the water demand of the mixture, which influences its consistency. The impact of PET fibers on compressive strength varies depending on fiber content and other factors. Some studies report a decrease in compressive strength with increased fiber volume, as fibers may disrupt the concrete’s matrix. However, optimal fiber content may help balance this. PET fibers contribute to increased tensile strength by bridging cracks within the matrix. This effect is more pronounced when the fibers are well distributed and the fiber volume is within an optimal range. The fibers improve the concrete’s resistance to bending and cracking. Similar to tensile strength, flexural strength benefits from the fiber reinforcement, enhancing the material's overall performance. The volume of fibers added to the mix is a critical factor in determining the mechanical properties. A balance must be struck to ensure that fiber content improves strength without adversely affecting other aspects like workability or compressive strength. The length, diameter, and aspect ratio of PET fibers also significantly affect performance. Longer fibers generally offer better reinforcement, improving crack resistance and tensile strength. The incorporation of blended cements, such as fly ash or slag, can impact the hydration process and the bonding between fibers and the matrix. Some studies suggest that the use of blended cement with pet fibers improves the long-term durability and mechanical properties of concrete. The review compares results from different studies and highlights how PET fiber properties (e.g., length, aspect ratio) and mix proportions influence the final concrete properties. These experiments indicate that optimal fiber volume and dimensions can significantly enhance concrete's performance, particularly in tensile and flexural strength. More studies are needed to determine the most effective fiber volume and distribution methods that maximize concrete performance without compromising other key properties like compressive strength or durability.

Mand Kamal Askar et al (2023) Plastic waste is a growing environmental concern, with significant amounts generated from industries, services, and municipal solid waste (MSW). The limited capacity of landfills and the long degradation period of plastics have led to increasing interest in recycling waste materials. One effective solution is incorporating plastic waste into construction materials, particularly concrete, to create sustainable or "green" concrete. Among the various plastics, polyethylene terephthalate (PET) has gained attention due to its availability and compatibility with cement-based composites Recycling PET waste in concrete is a promising approach to promoting sustainability in the construction industry. While PET-modified concrete may exhibit some mechanical limitations, these can be mitigated through optimized mix design and surface treatment techniques. Future research should focus on large-scale applications, long-term durability, and structural performance to enhance the viability of PET-based green concrete.

Weiwen Li et al (2022) the environmental impact caused by the production process of ordinary Portland cement (OPC) concrete is a major challenge that requires demanding solutions in the construction sector. In the process of substituting OPC concrete production, the development of geopolymer concrete (GPC) is considered as a major breakthrough. However, research works related to the durability of fiber-reinforced geopolymer in several corrosive environments, including sewage conveyer concrete pipelines, wastewater treatment facilities, and offshore structures, are limited compared to other types of concrete structures. Such studies are essential to estimate the long-term performance of concrete structures in extensive engineering applications. This review highlights the potential of GPC as a sustainable alternative to OPC concrete with enhanced durability properties. The research underscores the role of calcium content and fiber reinforcement in influencing performance under aggressive environmental conditions. However, further studies are necessary to address gaps related to multi-environmental exposures and hybrid reinforcement systems, paving the way for broader applications in wastewater treatment, offshore structures, and other critical infrastructure. Increasing the cement content from 10% to 20% had no significant effect on the properties of fly-ash-based geopolymer concrete with crumb rubber and steel fiber when subjected to normal and acidic environmental exposure.

Binija Chacko et al (2021) this study explores the innovative use of PET fibers, derived from plastic waste, in enhancing the mechanical properties of concrete, aligning with the principles of zero plastic waste and sustainable construction practices. The research focuses on M25-grade concrete and examines how various aspect ratios (AR) of PET fibers (AR 2.5, AR 7.5, AR 10) and fiber volumes (0.4%, 0.9%, and 1.4% by cement weight) affect its strength parameters. The aim is to assess the feasibility of incorporating these fibers into concrete as a sustainable and cost-effective alternative. The study's findings have the potential to advance the adoption of fiber-reinforced concrete in construction, promoting sustainable practices and addressing pressing environmental concerns. Improved structural properties of concrete, making it suitable for diverse applications. Reduction of plastic waste and greenhouse gas emissions through the recycling of PET bottles. Samples cured for 28 days and subjected to strength tests as per IS codes. PET fibers processed to specific aspect ratios and integrated into concrete mixtures. Varying aspect ratios and volumes are tested to identify the optimal mix for maximum strength benefits.

Junaid Ahmad et al (2021) this study provides valuable insights into the *load-moment (P-M) interaction behavior* **of** *geopolymer concrete (GPC)* filled *fiber-reinforced polymer (FRP)* tube circular columns internally reinforced with FRP bars. This analytical framework could further benefit studies on *sustainable materials* and *hybrid reinforcement systems***,** aligning with advancements in *green construction technologies*. The results confirm that confined GPC strength and FRP reinforcement play a crucial role in enhancing structural performance under combined axial and flexural loading. The model can be used to optimize design parameters for FRP-confined GPC columns in structural applications. Validation was performed by comparing the model predictions with *experimental results*, demonstrating *conservative accuracy* in the predictions.

Samuela et al. (2020) focuses on the use of PET (Polyethylene Terephthalate) plastic in shredded form as reinforcement in cement concrete. PET plastic is chosen due to its wide availability, especially in the Oceania tropical region, including Fiji. The research compares the compressive and tensile strength of plain cement concrete with PET fiber-reinforced cement concrete through laboratory experiments. The results of these experiments are then compared to findings from existing literature on the topic.

Using shredded PET as reinforcement in concrete aims to enhance the material properties of concrete while also contributing to the recycling of plastic waste, which is an important environmental consideration. The findings from this study may help in assessing the viability and performance of such concrete mixes in real-world applications, particularly in regions where plastic waste disposal is a concern.

Godage Priyanka Sanjay et al (2019) this research paper investigates the use of waste Polyethylene Terephthalate (PET) fibers as an additive in concrete, focusing on improving the mechanical properties of concrete. The study aims to tackle the challenges of PET bottle recycling, particularly in developing countries where recycling facilities are limited. The research tests the performance of PET fiber-reinforced concrete for two grades of concrete (M20 and M30) by replacing a portion of the fine aggregate with PET fibers. The PET fiber replacement ranged from 0.0% to 2.0%. The experimental tests conducted on concrete specimens, including cubes, cylinders, and beams, measured their compressive strength, split tensile strength, and flexural strength after 28 days of curing. The findings reveal that the optimal performance was observed at a 1.5% fiber volume replacement in the fine aggregate, which resulted in the highest compressive, split tensile, and flexural strengths.

The study concludes that incorporating waste PET fibers into concrete not only contributes to solving the environmental issue of PET bottle waste but also enhances the mechanical properties of concrete, making it a valuable alternative for sustainable construction practices.

Babafemi et al. (2018) highlights the potential of using recycled plastic as a partial replacement for conventional aggregates or as embedded components in concrete. While the use of recycled plastic affects properties such as water absorption and permeability, the concrete generally maintains sufficient durability for various applications. This may depend on the proportion and type of recycled plastic used. Despite changes in mechanical and durability properties, the modified concrete often fulfills the requirements for many structural and non-structural applications, particularly where lightweight, insulation, or sustainability are priorities. The use of recycled plastic in concrete contributes to waste management and reduces the environmental impact by minimizing the use of non-renewable natural resources. Emphasized the importance of optimizing mix proportions and understanding the influence of plastic type and size to improve the performance of such concrete for specific engineering applications.

Malik et al. (2018) highlighted that the incorporation of *Polyethylene Terephthalate (PET) fibers* in concrete has a dual effect. The inclusion of PET fibers enhances the workability of the concrete mix, improving its ease of placement and compaction. The use of PET fibers marginally reduces the overall density of the concrete. As a result, the concrete can be classified as *lightweight concrete* based on its unit weight. This makes the material particularly suitable for applications where reducing structural weight is a priority, such as in high-rise buildings or retrofitting projects. The findings emphasize the potential of using recycled plastic materials like PET fibers in concrete production to achieve sustainability objectives while also enhancing certain performance characteristics.

Shahidan et al. (2018) conducted experiments to investigate the effects of recycled PET (polyethylene terephthalate) fibers on the properties of concrete. Their findings indicated that as the percentage of recycled PET fiber increased, the following trends were observed. The workability of the concrete, measured by the slump test, reduced with higher PET fiber content. This is typically because the fibers can create more friction and resistance within the mix, making it harder for the concrete to flow easily. The compressive strength of the concrete decreased as the amount of PET fiber increased. This could be due to the disruption of the concrete's cohesive structure by the fibers, which may hinder the formation of a dense, strong matrix. The study found an increase in the splitting tensile strength with higher amounts of recycled PET fibers. This could be attributed to the fibers' ability to bridge cracks and enhance the concrete's ability to resist tensile stresses, thus improving its performance under tension. These results are consistent with many studies that show how the inclusion of fibers (especially recycled ones like PET) can modify the mechanical properties of concrete in different ways.

Saxena et al. (2018) investigates the effect of increasing amounts of Plastic PET waste on concrete properties. The findings indicate that as the percentage of PET waste increases in the concrete mix, there is a reduction in key properties such as workability, compressive strength, flexural strength, and both dynamic and static modulus of elasticity. Despite these decreases in strength-related properties, the study concludes that concrete containing PET waste may still be suitable for applications where abrasion resistance is more critical than strength, such as in road pavement and other areas where high strength is not a primary concern. This suggests that while PET waste can be used in concrete, careful consideration of its impact on the material's performance is necessary, depending on the intended application.

Samuela Loaloa Vukicea et al (2017) study highlights a critical environmental issue and demonstrates an innovative approach to addressing it by integrating recycled Polyethylene Terephthalate (PET) into concrete. Growing plastic waste, especially PET, poses a serious environmental threat due to its non-biodegradability. Recycling PET into construction materials addresses both environmental sustainability and functional utility. Its properties make it a suitable substitute in composite materials like concrete. PET fibers are integrated into ordinary concrete to produce PET Fiber Reinforced Concrete (PFRC). PFRC leverages PET's properties to enhance concrete's mechanical performance. Concrete samples were prepared with 0%, 1%, 2%, and 3% PET fiber by weight of cement. Compressive and split tensile strength tests were conducted at curing ages of 7, 14, and 28 days. Compressive and split tensile strength improved with increasing PET fiber content. Incorporating recycled plastic reduces the density and compressive strength of concrete compared to conventional concrete. The decrease is attributed to the lower stiffness and strength of plastic compared to natural aggregates.

Anathi et al. (2017) discussed the use of Plastic PET fibers as a sustainable solution to reduce plastic waste and improve the properties of concrete. By adding recycled PET plastic fibers into concrete, the study found that this practice not only helps mitigate plastic pollution but also enhances the mechanical properties of concrete, such as compressive strength and split tensile strength. The incorporation of PET fibers likely contributed to better internal bonding and improved crack resistance, as the fibers act as reinforcement within the matrix. The use of waste plastics in concrete aligns with the broader movement toward eco-friendly construction practices, offering benefits such as reducing the environmental impact of plastic waste, improving durability, and potentially reducing the overall cost of concrete production. This research is significant as it explores ways to both reuse waste materials and enhance the material properties of concrete, providing an innovative solution to two pressing challenges: plastic pollution and the need for stronger, more durable construction materials.

Dinesh and Rao (2017) conducted an investigation on the use of recycled PET (Polyethylene Terephthalate) fibers in concrete. Their study examined the impact of adding PET fibers at varying content levels of 0.5%, 1%, and 1.5% on concrete specimens. The results indicated that the inclusion of PET fibers decreased the workability of the concrete mixture. However, significant improvements were noted in the compressive, split tensile, and flexural strengths of the concrete. The optimal strength across all types of strength tests was observed at a 0.5% fiber content. Moreover, the study found that the addition of PET fibers did not substantially alter the mortar compressive strength, suggesting that the fiber content primarily affects the overall mechanical performance without changing the mortar's inherent properties. The research emphasized that the use of recycled materials, such as PET fibers, offers potential as a sustainable approach in concrete production and that ongoing advancements in this technology could further enhance the properties of concrete. It was also proposed that using PET bottles as reinforcing fibers could improve the ductility of concrete, providing added flexibility to concrete structures.

Subramani et al (2017) discussed the use of fibers, particularly PET (polyethylene terephthalate) fibers, as building materials. Their study suggests that PET fibers can be incorporated into construction materials up to a certain limit, with 4% being identified as the optimum percentage. This means that adding up to 4% PET fibers to concrete or other building materials can enhance the material properties, likely improving aspects such as strength, durability, and resistance to cracking. However, beyond this percentage, the performance might not improve or could even degrade due to potential issues like fiber clumping or incompatibility with the matrix material.

Guendouz et al. (2016), the researchers explored the effects of incorporating plastic waste into sand concrete, specifically focusing on plastic powder (LDPP) and plastic fibers (LPE). The study concluded that the mechanical properties of the concrete, such as compressive strength, flexural strength, and durability, were positively influenced by the type of plastic waste added. The optimal amounts for achieving the best mechanical performance were found to be. The addition of plastic waste not only improved the mechanical properties of the concrete but also contributed to sustainability by reducing the amount of plastic waste. However, exceeding these optimal percentages could result in a reduction of strength, indicating the importance of maintaining the right balance of plastic waste in the mix.

Koo et al. (2014) demonstrates the successful performance verification of a newly developed Hwangtoh concrete mixed with short recycled PET fibers. Their results validate the potential of using this eco-friendly concrete, reinforced with recycled PET fibers, as a structural material in modern construction. The addition of recycled PET fibers enhances the mechanical properties of the concrete, making it a promising alternative for sustainable building materials. This study contributes to the growing field of incorporating waste materials like recycled plastics in construction to improve both the performance and environmental sustainability of concrete.

Raju and Chauhan (2014) emphasized the importance of enhancing the surface properties of plastic fibers to improve their bond behavior with the matrix in composite materials. They suggested that for achieving optimum strength, it is crucial to focus on two main aspects: the matrix hydration process and the effects of the plastic fibers on this process. By modifying the surface properties of the plastic fibers, their interaction with the matrix can be improved, which can lead to better bonding and, consequently, enhanced mechanical performance in concrete or other composite materials.

Methodology :

This review is based on an extensive literature survey of experimental research conducted on PET fiber-reinforced concrete. The methodology involves:

- *Selection of Literature*: Research articles, conference papers, and technical reports published in reputable journals and databases were reviewed. The selection criteria included studies that focused on the mechanical and durability properties of PET fiber-reinforced concrete.

- *Data Collection and Analysis*: The studies were analyzed for parameters such as fiber content, length, aspect ratio, mixing methods, and the impact on concrete properties. Quantitative data were extracted and compared to evaluate trends and significant findings.
- *Classification of Research Findings*: The reviewed studies were categorized based on different aspects such as mechanical properties (compressive, tensile, and flexural strength), durability aspects (water absorption, permeability, and shrinkage), and workability of PET fiber concrete.
- *Comparative Assessment*: A comparative analysis was performed to identify the advantages, limitations, and gaps in existing research, leading to a comprehensive understanding of the feasibility and effectiveness of PET fiber in concrete applications.

Conclusion :

The review of experimental research on PET fiber-reinforced concrete suggests that incorporating PET fibers enhances certain mechanical and durability properties of concrete, particularly tensile and flexural strength. Key conclusions include:

- PET fibers improve crack resistance and reduce shrinkage, contributing to the longevity of concrete structures.
- The optimal PET fiber content typically ranges between 0.5% to 1.5% by volume, beyond which workability issues and fiber clustering may occur.
- Proper mixing techniques and fiber dispersion methods are critical for achieving uniform fiber distribution and maximizing the benefits of PET fibers.
- While PET fiber-reinforced concrete demonstrates potential for sustainable construction, further studies are required to optimize fiber dosage, understand long-term durability aspects, and assess large-scale application feasibility.
- PET fiber utilization in concrete aligns with sustainability goals by reducing plastic waste and promoting eco-friendly construction practices.

This review highlights the promising application of PET fibers in concrete and encourages further experimental and field studies to establish standardized guidelines for practical implementation in construction.

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